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Stratospheric age tracers: re-evaluating old friends and making new ones

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Stratospheric transport, specifically the mean meridional or Brewer-Dobson circulation, cannot be measured directly, but can be inferred from trace gas distributions. For example, the transit time of air from the troposphere to a given location in the stratosphere is described by the ‘age of the air’, determined by observations of inert chemical tracers. Ideal tracers should have no stratospheric sources or sinks and should have shown a linear tropospheric trend for at least a decade. Sulphur hexafluoride, SF_6, is a very long-lived compound that is often used as an atmospheric transport tracer. Use of SF_6 assumes an accurate understanding of its atmospheric lifetime, which is currently estimated to be around 3200 years. However, as SF_6 loss mainly occurs in the rarely-sampled mesosphere, loss rates must be determined indirectly. Recent evidence suggests that SF_6 loss mechanisms may be underestimated, reducing its atmospheric lifetime. This would complicate the use of SF_6 as a tracer of stratospheric transport. In this work we collate data from five stratospheric aircraft and balloon campaigns stretching over 17 years with long-term tropospheric trends from Cape Grim, Tasmania to re-investigate the suitability of this age tracer. At the same time, we assess alternative transport tracers, such as CF_4(PFC-14), C_2F_6 (PFC-116), C_3F_8 (PFC-218) and CHF_3 (HFC-23), HFC-125 and HFC-227ea. Mean ages derived from each tracer are compared, along with an in-depth analysis of the uncertainties involved in these calculations. Key uncertainties associated with calculating the age of air from chemical tracers include: (1) uncertainties in the atmospheric measurements, (2) uncertainties during the processing (namely applying a polynomial fit) of the tropospheric trend for input into the age calculation and (3) uncertainties in the assumptions involved in the age of air calculation. Our results indicate good suitability for some of these gases, in terms of their inertness, tropospheric growth rates and measurement precisions, to serve as tracers to investigate stratospheric transport.